**PATENT APPLICATION**

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In re the Application of

Shinya Kobayashi — Group Art Unit: 2853

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For: LINE SCANNING TYPE INK JET RECORDING DEVICE CAPABLE OF FINELY AND INDIVIDUALLY CONTROLLING INK EJECTION FROM EACH NOZZLE

DECLARATION UNDER 37 CFR §1.131



Director of the U.S. Patent and Trademark Office
Washington, D.C. 20231

Sir:

I, Hiromi Matsushita, working at Japanese Patent Attorney's Offices named "KITAZAWA & KOIZUMI" located in Sigma Yushima Bldg. 6F, No. 37-4, Yushima 3 chome, Bunkyo-ku, Tokyo, 113-0034, Japan, hereby declare that:

I am familiar with both English and Japanese languages;

I believe the attached English translations are true and complete translations made by me of the certified copies of Japanese Patent Application No. 2000-75116 filed March 17, 2000 in the Japan Patent Office on which international priority is claimed in the present application;

I have reviewed and understand the contents of this Declaration, and that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the

United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: Sep. 11, 2003

Hiromi Matsushita

[Document Name] Specification

[Title of the Invention] Ink Jet Recording Device

[Claims]

[Claim 1]

An ink jet recording device comprising a recording head capable of controlling ejection and non-ejection of an ink droplet from a nozzle by applying pressure to ink in an ink chamber opened to the nozzle in response to a recording signal, the recording head with a plurality of nozzles being disposed in a manner that the nozzles face a recording medium and impinging ink droplets on the recording medium at predetermined pixel positions, thereby forming a recording image on the recording device with a collection of recording dots formed by the ink droplets, the ink jet recording device being characterized by comprising:

a means for converting the recording signal to a drive data that is smaller than the pixel by using a nozzle profile data indicating a pulse voltage waveform to be applied to a piezoelectric element and a generation timing thereof for each nozzle.

[Claim 2]

The ink jet recording device according to claim 1, characterized by further comprising a means for switching a plurality of pulse voltage waveforms for each nozzle in accordance with the nozzle profile data indicating the

plurality of pulse voltage waveforms and the generation timing thereof for each nozzle and an ink-non-ejecting period, or in accordance with a signal received from an external device when such a recording condition as a material or speed of recording sheet, nozzle temperature, or ink is changed.

[Claim 3]

The ink jet recording device according to claim 1, characterized by further comprising a specifying means for specifying an ejection amount of the ink droplet and an impinging position on the sheet with respect to a scanning direction or a means for measuring a center position of a recording dot with respect to the scanning direction, and a means for updating the nozzle profile data based on them.

[Claim 4]

The ink jet recording device according to claim 3, characterized by that the means for updating the nozzle profile data includes a first stage updating means for updating the pulse voltage waveform to achieve the uniform ejection amount among the nozzles and a second stage updating means for aligning the impinging positions on the sheet with respect to the scanning direction for the nozzles by updating the generation timing of the pulse voltage waveform and updates in this order.

[Claim 5]

The ink jet recording device according to claim 4, characterized by that the first stage updating means updates the pulse voltage waveform so as to change one drive pulse time width, a no-voltage-application period of a drive pulse that includes the no-voltage-application period in the middle of a drive pulse time, or a voltage-apply duty of a plurality of drive pulses.

[Claim 6]

The ink jet recording device according to claim 5, characterized by further comprising a means for smoothing a voltage of a signal to drive the piezoelectric element.

[Claim 7]

The ink jet recording device according to claim 1 or 2, characterized by further comprising a deflection electric field generation means for generating an electric field in a space between a recording head ejection surface and the recording sheet, the electric field having a component in a direction substantially perpendicular to an ink droplet ejection direction and a scanning direction, and an charging electric field generation means for generating a charging electric field in the nozzle for ejecting the ink droplet, the charging electric field having a component in a direction parallel to the ink droplet ejection direction.

[Claim 8]

The ink jet recording device according to claim 7,

characterized by further comprising a specifying means for specifying an ejection amount, an impinging position on the sheet with respect to the scanning direction, and an impinging position on the sheet with respect to a direction perpendicular to the scanning direction of the ink droplet, or a measuring means for measuring a center position of a recording dot with respect to the scanning direction and the direction perpendicular to the scanning direction, and a means for updating the nozzle profile data based on them.

[Claim 9]

The ink jet recording device according to claim 8, characterized by that the means for updating the nozzle profile data includes a first stage updating means for updating the pulse voltage waveform so as to achieve the uniform ejection amount among the nozzles by changing a no-voltage-application period of a drive pulse having the no-voltage-application period in the middle of a drive pulse time or by changing a voltage application duty of a plurality of drive pulses, a second stage updating means for updating the pulse voltage waveform to align the impinging positions with respect to the direction perpendicular to the scanning direction by changing one drive pulse time width, and a third stage updating means for aligning the impinging positions with respect to the scanning direction by updating the generation timing of the pulse voltage waveform.

[Claim 10]

The ink jet recording device according to claim 9, characterized by further comprising a means for smoothing a voltage of a signal to drive the piezoelectric element.

[Claim 11]

The ink jet recording device according to any one of claims 1 to 10, characterized by further comprising a means for leveling the generation timing of the pulse voltage waveform by updating the generation timing of the pulse voltage waveform of the nozzle profile data.

[Claim 12]

The ink jet recording device according to any one of claims 1 to 10, characterized by further comprising a means for setting a time resolution per bit that defines the pulse voltage waveform, the time resolution being included in the nozzle profile data, the means setting the time resolution without regarding a time resolution per bit that defines the generation timing of the pulse voltage waveform.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a drop-on-demand type ink jet printer including piezoelectric elements, and particularly to a high-speed recording device capable of reliably printing high quality images.

[0002]

[Related Art]

There has been proposed a line-scan type ink jet recording device as an ink jet recording device that prints at high speed. In this device, an elongated ink jet recording head with a row of nozzles for ejecting ink droplets is disposed in confrontation with a recording sheet across the entire width of the surface of the recording sheet, and impingement of ink droplets ejected from the nozzles onto the surface of the recording sheet is selectively controlled in accordance with a recording signal. At the same time, the recording sheet is transported rapidly, which serves as a main scanning. This main scanning of the sheet and the control on impingement of ink droplets on the recording sheet together control recording dot formation on scanning lines, thereby obtaining a recording image on the recording sheet.

[0003]

Various types of line-scan ink jet recording devices have been proposed, such as devices that use a continuous ink jet type recording head as a recording head and devices that use a drop-on-demand type recording head.

[0004]

Although drop-on-demand ink jet type line-scan ink jet recording devices have a slower printing speed than do

continuous ink jet type devices, they have an extremely simple ink system and so are well suited for a general-purpose high-speed recording device. A recording head for the drop-on-demand ink jet type line-scan ink jet recording device is a line-scan recording head that includes a row of nozzles each ejecting an ink droplet when pressure is applied to ink filled in an ink chamber opened to the nozzle upon application of a driving voltage to a piezoelectric element or a thermal element. That is, the device is for printing by a line-scan recording head including the same number of nozzles as the scanning lines, and this type of recording head has well been proposed in, for example, Japanese Patent-Application Publication No. HEI-11-78013.

[0005]

[Problems to be Solved by the Invention]

Although a conventional line-scan ink jet recording device including the above-described drop-on-demand ink jet recording head can configure a high-speed recording device in an easy manner, there has been a following problem.

[0006]

Because nozzles having the same number of nozzles as scanning lines on a recording sheet and being opened to the nozzles are used, in order to print at a recording resolution of 300 dpi (dot/inch) on a 18-inch wide continuous recording sheet, for example, the number of

scanning lines is 5,400. 5,400 nozzles are needed in a recording device for monochrome printing, and 21,600 nozzles are mounted on a color recording device for printing with four colors of ink.

[0007]

In the drop-on-demand ink jet type recording head, because nozzles can be formed with high accumulation, it is possible to realize such an arrangement of a large number of nozzles. However, there was a problem for ensuring quality of recording images. It is difficult to produce such a large number of nozzles with the same size. An ink ejection characteristic varies among the nozzles because of production variation or the like. For example, when there is a significantly large difference in a size, a shape, or an impingement position on a sheet among ink droplets ejected from adjacent nozzles, undesirable lines and an uneven density will appear to degrade the printing quality. However, producing a recording head including a large number of nozzles with a satisfactory level of variation among the nozzles makes the manufacture yield extremely bad. Also, even if the nozzles have the uniform characteristics at the beginning, the ejection characteristics may become uneven between adjacent nozzles during operation of the recording device for some reasons. Thus, there was a problem for ensuring the recording quality.

[0008]

This invention solves the above-mentioned conventional problem. The object of this invention is to provide, in a line-scan ink jet recording devices including a drop-on-demand ink jet type recording head, a high-speed ink jet recording device capable of reliably printing high-quality images.

[0009]

[Means to Solve the Problems]

In order to attain the above object, the present invention provides an ink jet recording device including a recording head capable of controlling ejection and non-ejection of an ink droplet from a nozzle by applying pressure to ink in an ink chamber opened to the nozzle in response to a recording signal, the recording head with a plurality of nozzles being disposed in a manner that the nozzles face a recording medium and impinging ink droplets on the recording medium at predetermined pixel positions, thereby forming a recording image on the recording device with a collection of recording dots formed by the ink droplets, the ink jet recording device being characterized by including: a means for converting the recording signal to a drive data that is smaller than the pixel by using a nozzle profile data indicating a pulse voltage waveform to be applied to a piezoelectric element and a generation

timing thereof for each nozzle.

[0010]

Further, in order to deal with a difference and a variation of ejection characteristics of nozzles, there is also provided a means for updating the nozzle profile data based on a specified impingement position on a sheet and on an ejection amount of an ink droplet or their measurement results.

[0011]

Further, in order to prevent a large number of pulse voltage waveforms from being generated at the same timing, a means for leveling the pulse generation timings is provided.

[0012]

Although the ejection amount of an ink droplet changes in accordance with the pulse voltage waveform, the ejection amount of the ink droplet does not change in accordance with the generation timing of the pulse voltage. Thus, first, a size and a shape of the ink droplet are determined by the pulse voltage waveform. Subsequently, the impingement position on the sheet in the scanning direction is determined by the generation timing of the pulse voltage waveform. In this manner, both the size and the shape of the ink droplet and the impingement position on the sheet can be changed independently, so a high-quality recording image can be always obtained.

[0013]

When a large number of the pulse voltage waveforms each for a nozzle are generated at the same timing, interference occurs to greatly fluctuate the size, the shape and the impingement position on the sheet of the ink droplet. When the generation timing of the pulse voltage of each nozzle is changed, the generation timing of pulse voltages may be the same. A high-quality recording image can be always obtained by adjusting the generation timing of the pulse voltages.

[0014]

[Embodiments of The Present Invention]

Hereinafter, preferred embodiments of the present invention will be described with reference to Figs. 1-13. First, a configuration of a printer system of the present embodiment will be described with reference to Figs. 2, 7, and 3.

[0015]

Fig. 2 shows an overall configuration of the printer system to which the present invention is applied. The printer system generally includes a computer portion 201 and an ink jet printer engine portion 202. The computer portion 201 includes a printer driver software which is divided into a RIP (raster image processor) portion 203 for developing a documents data to a bitmap data and a nozzle data converting

portion 204. The RIP portion 203 is the same as the conventional one. The nozzle data converting portion 204 is a new portion provided by this invention. The printer engine portion 202 includes a controller 205, a piezoelectric element driver 206, a recording head 207, and a sheet feed unit 208.

[0016]

Fig. 7 shows a simplified view of an ejection surface of the recording head 207. The x and y coordinate axis are defined on the ejection surface (y direction is a recording sheet transport direction). A center of each nozzle is expressed by the x and y coordinate. A unit is a unit of length, which is μm (sampled at 4800dpi on program in this embodiment). A resolution specification of the printer engine portion 202 in this embodiment is 300dpi in both the x and y axis directions. Because a nozzle pitch of adjacent nozzles is greater than 300dpi, the nozzles are aligned in a slanting direction as shown in Fig. 7 so as to realize the uniform 300dpi with respect to the x direction. In other words, in this embodiment, there are provided ten small heads, each having 512 nozzles aligned at a nozzle pitch of 32.5 dpi and is disposed in a slant by an angle θ of approximately 82.8 degrees. This provides a total of 5,120 nozzles. Accordingly, a print width is approximately 17 inches. In case of color, a plurality of this recording

heads 207 are aligned. However, in order to simplify the explanation, it is assumed that there is only one recording head. It is the same about other recording head when aligning a plurality of the recording heads.

[0017]

Fig. 3 shows configuration of the nozzle. 301 is an orifice, 302 is a pressure chamber, 303 is a diaphragm, 304 is a piezoelectric element, 305 is a signal input terminal, 306 is a piezoelectric element supporting substrate, 307 is a restrictor, which connects a common ink supply path 308 and the pressure chamber 302 and controls an ink flow to the pressure chamber 302, 309 is a resilient member (silicon adhesive, for example) which connects the diaphragm 303 and the piezoelectric element 304, 310 is a restrictor plate which forms the restrictor 307, 311 is a pressure chamber plate which forms the pressure chamber 302, 312 is an orifice plate which forms the orifice 301, 313 is a supporting plate which reinforces the diaphragm.

[0018]

The diaphragm 303, the restrictor plate 310, the pressure chamber plate 311, and the supporting plate 313 are formed from stainless steel, for example. The orifice plate 312 is formed from nickel material. The piezoelectric element supporting substrate 306 is formed from an insulating material, such as ceramics and polyimide.

[0019]

Ink flows from above to below through the common ink supply channel 308, the restrictor 307, the pressure chamber 302, and the orifice 301 in this order. The piezoelectric element 304 deforms when a voltage is applied to the signal input terminal 305, and maintains its initial shape when a voltage is not applied.

[0020]

Next, a printing operation in this printing system will be described while referring to Figs. 2, 6, 8, and 9.

[0021]

The RIP portion 203 in the computer portion 201 converts the document data 209 to print into bitmap data 210, which has a resolution in accordance with specifications of the ink jet printer engine portion 202. In this embodiment, the bitmap data 210 is one-dot/one-bit data for 300 dpi. "1" represents a colored dot and "0" represents uncolored dot. Then, the nozzle data converting portion 204 creates a driving data 212 of 4800dpi in horizontal direction and 300dpi in vertical direction to be described below, based on the bitmap data 210 and a nozzle profile data 211, which is prestored in the computer portion 201.

[0022]

Fig. 6 shows a file structure of the nozzle profile data 211. The nozzle profile data 211 of this embodiment is

a simple table data. In the first column, nozzle numbers are listed. Because 5,120 nozzles are formed in the print head 207 of this embodiment, the nozzle are numbered from 1 to 5,120. The x coordinates of the second column are the x coordinate values (μm) of the nozzles shown in Fig. 7. These values are referred to only for arranging the nozzles in ascending order and are not used in this embodiment. The y coordinates of the second column are used in this embodiment. In this embodiment, a generating timing of a driving pulse voltage waveform formed by a pulse data described next is determined based on the y coordinate values. Accordingly, although the y coordinate values are initially the y coordinate values (μm) of the nozzles shown in Fig. 7, the y coordinate values are changed when the generating timings are corrected. That is, although it actually indicates the generating timing of the driving pulse voltage waveform by the position, it is simply described as a nozzle y coordinate in this embodiment.

[0023]

Fig. 8 shows a definition of the pulse data. The pulse data includes two-byte Lbyte (a7, a6, ... a0) and Rbyte (b7, b6, ... b0). a7 and b7 represent MSB, and a0 and b0 represent LSB. When a time duration required for recording a single dot is Td (μs), each bit is a single bit data which is allocated to minute time of the 1/16 as shown

in Fig. 8. A value "1" indicates voltage application to the piezoelectric element 304, and a value "0" indicates voltage non-application to the piezoelectric element 304. This pulse data represents a voltage waveform of the pulse that drives the piezoelectric element 304 of each nozzle. The value of a pulse voltage is constant in this embodiment.

[0024]

Returning to Fig. 6, the pulse data 1 is used for ink ejection, that is, the pulse data 1 defines the pulse voltage waveform generated when the bitmap data 210 is colored data "1". On the other hand, the pulse data 2 is used for ink non-ejection, that is, the pulse data 2 defines the pulse voltage waveform generated when the bitmap data 210 is uncolored data "0". The pulse is called dummy pulse and generated for regulating interference between the nozzles. In this embodiment, the rest of pulse data including the pulse data 3 is not used. However, when recording characteristic is changed because of, for example, change in recording sheet material, printing speed, nozzle temperature, and type of ink to be used, then according to a signal from a sensor or the like which detects the change, the pulse data 1 is replaced by any other suitable pulse data for each dot to be recorded, so that a pulse voltage waveform optimal for printing images with maximum possible quality can be formed in accordance with the printing

condition.

[0025]

Fig. 9 shows a converting method for converting the bitmap data 210 to the pulse replacing data. The pulse replacing data is not shown in Fig. 2 because the pulse replacing data appears for explanation in the middle of converting the bitmap data 210 into the driving data 212. The nozzle data converting portion 204 first replaces the bitmap data 210 with the pulse data as described above, thereby creating the pulse replacing data. Specifically, the bitmap data 210 having the value "1" is replaced by the Lbyte and the Rbyte of the pulse data 1, and the bitmap data 210 having the value "0" is replaced by the Lbyte and the Rbyte of the pulse data 2. Because one bit of the bitmap data 210 is replaced by 16 bits, the resolution in the y direction of the pulse replacing data has 4800 dpi. That is, the data amount is increased to 16 times the amount of the bitmap data 210.

[0026]

Then, the nozzle data converting portion 204 converts the pulse replacing data into the driving data 212 for each nozzle based on the corresponding y coordinate value of each nozzle. Specifically, the pulse replacing data of each nozzle is shifted in the y direction by the corresponding y coordinate value, thereby producing the driving data 212.

Because the pulse replacing data has a resolution of 4800 dpi in the y direction, the pulse replacing data can be sifted in a precise manner, and the driving pulse can be generated at a precise timing for each nozzle.

[0027]

Returning to Fig. 2, the printing operation will be explained further. The driving data 212 generated in this manner may be temporarily stored in a memory provided to the computer portion 201. Then, printing may be executed when a plurality of pages worth of driving data 212 is stored in the memory. Alternatively, printing may be executed every time when one page worth of driving data 212 is generated. The following explanation will be provided for the latter case.

[0028]

When the nozzle data converting portion 204 has completed the converting, then the controller 205 controls the sheet feed unit 208 to feed a recording sheet. When a print start position is detected, then the controller 205 receives the driving data 212 from the computer portion 201 and transmits the same to the piezoelectric element driver 206. The piezoelectric element driver 206 generates a high voltage driving signal 213 based on the driving data 212. The driving signal 213 is then input to the signal input terminal 305 of the corresponding piezoelectric element 304

of a multi-nozzle provided to the print head 207. At this time, because there are a large number of nozzles, when the driving signal 213 is output from the computer portion 201, parallel-serial conversion is performed to reduce the number of signal lines. Then, when the driving signal 213 is input to the piezoelectric element driver 206, serial-parallel conversion is performed to return the number of signal lines. Because these conversions are well-known techniques, detailed explanation is omitted here. Then, the piezoelectric element 304 deforms in response to the driving signal 212, and an ink droplet is ejected from the nozzle, so an image 214 is formed on the recording sheet. The explanation of the operation in the case of printing by this printer system is finished.

[0029]

Hereinafter, problems raised in the usual recording (not controlled at all) by the above-mentioned printer system are explained with reference to Figs. 4 and 5.

[0030]

Fig. 4 shows a printing result obtained by the above-mentioned printer system. The recording head 207 is disposed with the ejection surface formed with the nozzles facing downward. The recording sheet 406 is transported upward with respect to the fixed recording head 207. Grids represented by broken line indicate pixel regions (not

written in fact). Because the resolution of the printer of this embodiment is 300dpi, each grid has a width of 85μm. Dots recorded at every other pixel are assigned with 401-405, respectively from the left. The dot 401 is formed in an ideal manner. The dot 402 is formed slightly above the target dot region. One possible explanation for this is that an ink droplet corresponding to the dot 402 is ejected at higher ejection speed.

[0031]

Fig. 5 is a side view showing the print head 207 and the recording sheet 406. Even if the ink is ejected at the time of when an ejection position y0 on the sheet 408 is located directly beneath the print head 207, because the sheet 408 is transported at speed Vp, the actual impingement position y will be:

[0032]

[E1]

$$y = y0 - D\frac{Vp}{Vd}$$

D: a distance between the nozzle and the sheet, Vd: an ejection speed (an average speed).

[0033]

That is, when the ejection speed Vd is faster than the others, then shifted to the upper side, and when the ejection speed Vd is slower than the others, shifted to the

lower side.

[0034]

Returning to Fig. 4, problems that occur when printing is continued will be explained. The dot 403 has a small diameter. Such a dot is formed when an ejection amount m from the nozzle is insufficient. The dot 404 has an elongated shape. Such a dot results when an ink droplet has a higher ejection speed at its leading portion than the ejection speed at its tailing portion. That is, the ink droplet has an elongated shape, rather than a spherical shape, when the ink droplet impinges onto the recording sheet. A smaller dot called satellite dot is formed below the dot 405. The satellite dot is formed when speed difference between a leading portion and a tailing portion of an ejected ink droplet is greater than that of the dot 404. An ink droplet being ejected is divided into two or more droplets in flight. When recorded dots include these unusual dots, quality of images will be undesirably degraded. Such problems occur in any type of drop-on-demand ink jet printer regardless of which type of ink or nozzles are used.

[0035]

In order to prevent these phenomena, the ejection speed Vd of the equation E1 is change to proper speed by controlling the pulse voltage and time width of pulse voltage waveform for driving the piezoelectric element 304,

so that impingement position y will be within target regions. If the recording head 207 has a small number of nozzles, a relationship between the ejection speed Vd and the ejection amount m is fixed. That is, when the ejection speed Vd is changed to a proper speed, then the ejection amount m of the ink droplet is automatically changed to a proper amount. However, in the line type recording head 207 as the device of this embodiment, elongated recording head 207 is constituted by a plurality of small recording heads such as the device described in Japanese Patent Application Publication (Kokai) No. HEI-11-78013. In this situation, the difference of the characteristic among the nozzles is great, and the relationship between the ejection speed Vd and ejection amount m varies greatly. For example, even if the ejection speed Vd is changed to a proper speed by controlling the pulse voltage and the time width of the pulse voltage waveform, the ejection amount m cannot be changed to an amount within the predetermined range. Furthermore, a defect dot like the dot 404, 405 is formed depending on a nozzle.

[0036]

In view of foregoing, the present invention provides a new controlling method for adjusting not only the ejection speed Vd but also both the impingement position y on the recording sheet and the ejection amount m of ink droplets.

[0037]

Hereinafter, the controlling method in the nozzle data converting portion 204 will be described with reference to Fig. 1, 10, 11, 17, 12, 18 and 19.

[0038]

Fig. 1 shows a configuration of the controlling method in the nozzle data converting portion 204. In this embodiment, the profile data update means 101 of the nozzle data converting portion 204 updates the y coordinate values and pulse data of the nozzle profile data 211 based on target impingement position y and ink ejection amount m. By converting a nozzle data using the converted nozzle profile data 211 and inputting the converted data into the ink jet printer engine portion 202, both the impingement position y and the ejection amount m of each nozzle can be adjusted. Hereinafter, the profile data update means 101 will be explained.

[0039]

Fig. 10 shows the characteristics between a driving pulse voltage (V) and an ejection speed Vd (m/s) and between the driving pulse voltage (V) and the ejection amount m (ng) of a usual ink jet nozzle shown in Fig. 3. The pulse voltage is a rectangular pulse. As indicated in Fig. 10, the ejection speed Vd and the ejection amount m change in the similar manner when the driving pulse voltage changes.

Accordingly, as mentioned above, when there were few nozzles, both the ejection speed Vd and the ejection amount m can be adjusted to proper values within target ranges only by changing the driving pulse voltage. However, when there are a large number of nozzles as in the present embodiment, even if the ejection speed characteristic is the same, the ejection amount m may greatly vary, as indicated by a nozzle characteristic of N1 and N2 in Fig. 10 for example. Accordingly, both the ejection speed Vd and the ejection amount m cannot be adjusted to a proper value within the target range at the same time only by changing the driving pulse voltage.

[0040]

Then, in this embodiment, the profile data update means 101 of Fig. 1 executes an updating process that includes the following two stages.

[0041]

(First Stage)

In the nozzle profile data 211 updating first stage, the ejection amount m is adjusted to a target value. The profile data update means 101 has a table indicating characteristic between the driving pulse voltage and the ejection speed shown in Fig. 10. The table could be obtained by measuring the characteristic of each nozzle in advance or performing printing test. In the latter case, a

measuring unit 102 is necessary for taking picture of a dot on the recording sheet by a CCD camera or the like and detecting a center position of the dot. Even if the measuring device 102 has low resolution, the measuring device 102 can measure with relatively high precision because measurements are not greatly influenced by external source, such as fluctuations in lighting. In this embodiment, a 600dpi CCD camera is used to obtain a photograph image at monochrome 256 tones, and the center position is determined by a well-known center of gravity measurement program. The test printing is repeated for different driving voltages. Then, the impingement positions y of those dots are detected, and the ejection speed Vd is calculated by the above (E1). In this manner, the table for the characteristic between the driving pulse voltage and the ejection speed is obtained.

[0042]

The profile data update means 101 determines the pulse data 1 based on the table of the characteristic between the driving pulse voltage and the ejection amount and on the ejection amount m and updates the nozzle profile data 211. However, in this embodiment shown in Fig. 2, the driving pulse voltage is constant, so the driving pulse voltage cannot be changed for each nozzle individually. In view of foregoing, the rising edge timing and falling edge timing of

a pulse voltage waveform are manipulated instead of manipulating the driving pulse voltage. This method will be explained next.

[0043]

Fig. 11 shows the characteristics between a driving pulse time width (μs) and an ejection speed Vd (m/s) and between the driving pulse time width (μs) and the ejection amount m (ng) of a usual ink jet nozzle shown in Fig. 3. The driving voltage is a rectangular-shaped single pulse. When resonant frequency of a nozzle is Tn (18μs in this embodiment), the ejection speed Vd and the ejection amount m have a maximum value when the driving pulse has a pulse width of Tn/2. Accordingly, when the time width of the driving pulse is set to somewhere around a region A at right side of Tn/2 shown in Fig. 11, the ejection amount m can be adjusted. Therefore, this characteristic between the time width of the driving pulse and the ejection amount may be replaced by the characteristic between the time width of the driving pulse and the ejection amount of the above-described embodiment.

[0044]

Fig. 17 shows a method to change a specific pulse data 1 by the profile data update means 101. The pulse data 1 of nozzle Nos. n1, n2, n3 is "07e0", "03e0", and "03c0", respectively, in hexadecimal number system. In this

embodiment, because the time duration Td for recording a single dot is 36μs, the time width of the driving pulse should be 13.5, 11.2, and 9(μs), respectively. Accordingly, the time width of the driving pulse for each nozzle can be changed individually, thereby properly changing the ejection amount m.

[0045]

In this embodiment, a means to manipulate the voltage of the driving pulse voltage waveform for each nozzle is replaced by a means to manipulate the time width of the driving pulse voltage waveform for each nozzle. Therefore, the piezoelectric element driver 206 can have a simple and compact circuit configuration, and also have an improved practical use as compared with the case of manipulating the voltage.

[0046]

However, in the region A of the characteristic shown in Fig. 11, the ejection speed Vd greatly changes compared with the ink ejection amount m. Accordingly, when the ink ejection amount m is changed, the ejection speed Vd changes greatly, so the impingement position y also changes greatly as will be understood from E1. Therefore, an efficiency of this correction is bad. Also, because the characteristic curve has a maximum value and does not change in uniformity, desired correction may not be achieved in a simple manner.

Here, this disadvantage is overcome by combining two or more pulses in the following manner.

[0047]

Fig. 12 shows characteristics between a voltage non-application time Tsplit (μs) and an ejection speed Vd(m/s) and between the Tsplit and an ejection amount M(ng) for when a driving pulse having a time width Tw is divided by a voltage non-application time with a time width Tsplit (μs) in the middle. The time width Tw is set to Tn/2 (=9μs) shown in Fig. 11. The same effect will be obtained by replacing the characteristic between the time width of the driving pulse and the ejection amount with this characteristic between the voltage non-application time Tsplit (μs) and the ejection amount m(ng).

[0048]

Fig. 18 shows a method of changing a specific pulse data 1 in the profile data update means 101. The pulse data 1 of the nozzle Nos. n1, n2, n3 is "03c0", "0340", and "02c0" respectively, in hexadecimal number system. In this embodiment, the time width of the pulse data is 9.0 (μs), and the voltage non-application time Tsplit (μs) at the central portions should be 0, 2.2, and 4.5 (μs). As described above, because the voltage non-application time can be changed individually for each nozzle, the ejection amount m can be changed to a proper amount.

[0049]

In this embodiment, in the characteristic between the voltage non-application time Tsplit (μs) and the ejection amount m (ng) shown in Fig. 12, the ejection speed Vd and the ink ejection amount m change in the similar manner. This contrast with the previous embodiment. Accordingly, the efficiency of the correction is improved in the same manner as the case of the characteristic between the driving pulse voltage and the ejection amount shown in Fig. 10. Moreover, because the change of the characteristic is a simple reduction, the correction can be easily performed.

[0050]

In this embodiment, the driving pulse voltage waveform is divided into two pulses while the time width of the driving pulse is unchanged. However, the driving pulse can be divided into three or more pulses. In this case, if a time resolution at the time of setup is insufficient, the number of the bits of the pulse data 1 can be increased and the dividing number of each dot can be increased. When a driving pulse is divided into a larger number of pulses while the time width of the driving pulse is unchanged, the pulse duty (a ratio of voltage apply time duration to a total time duration of pulse voltage) usually has a characteristic similar to that of the driving pulse in the characteristic between the driving pulse voltage and the

ejection speed shown in Fig. 10. For example, when the right and the left of Fig. 10 and Fig. 12 is reversed, then they show the similar characteristics. One possible explanation for this is that the piezoelectric element driver 206 shown in Fig. 2 becomes incapable of responding to an input signal, thereby dropping effective voltage. When the response capability of the piezoelectric element driver 206 is sufficiently high, high frequency component of the output voltage unstabilizes the characteristics shown in Fig. 12. In this case, the characteristics can be stabilized by using a low pass filter described next.

[0051]

Fig. 19 shows a smoothing circuit for multiple pulse driving. The capacitance 1901 shown in Fig. 19 is an equivalent circuit of the piezoelectric element 304 shown in Fig. 3. Conventionally, the piezoelectric element driver 206 is directly connected to the capacitance 1901. However, when the response capability of the piezoelectric element driver 206 is too high, a resistance R or a capacitance C is provided therebetween as shown in Fig. 19. This configuration smoothes the voltage applied to the capacitance 1901 in a suitable manner, thereby stabilizing the characteristic between the pulse duty and the ejection amount.

[0052]

The ejection amount m is adjusted by updating the nozzle profile data 211 at the above-described first stage. However, because the ejection speed Vd differs among the nozzles, as (E1) shows, the impingement positions are still out of alignment.

[0053]

(Second Stage)

In the nozzle profile data 211 updating second stage, the impingement position y of each nozzle is adjusted to a target position. As shown in Fig. 1, a test printing is performed, and the measuring unit 102 measures the actual impingement position y. The measured impingement position y is input to the profile data update means 101. The profile data update means 101 adds a difference between the measured impingement position y and the target impingement position y to the nozzle coordinate value y of the nozzle profile data 211. As the (E1) shows, this process adjusts y0, so the impingement position y is changed properly.

[0054]

With the above-described two-stage procedure, both the impingement position y and the ejection amount m for each nozzle can be adjusted to a value within a predetermined region. Therefore, in a line-scan type ink jet recording device including a drop-on-demand ink jet print head, a high-speed ink jet recording device capable of reliably

printing a high quality image can be provided.

[0055]

Next, other embodiment will be explained with reference to Fig. 13.

[0056]

Conventionally, when a plurality of nozzles are driven, the method called multisift was used in order to reduce interference on the ejection speed Vd and the ejection amount m among the nozzles. For example, when the time width of a driving pulse is as short as 10μs, whereas a dot frequency for repeatedly recording a dot is 100μs, nozzles are divided into a plurality of groups and the driving pulses corresponding to the nozzles in the same group are controlled not to be output in synchronization. It is proved that the interference is suppressed by this. In this invention, it is difficult to perform the multishift, because a generation timing of a driving pulse differs among the nozzles as a result of the correction of the impingement position (the second stage). Therefore, the interference may cause an undesirably large effect.

[0057]

In order to overcome these problems, according to this device, a nozzle profile data 211 adjusting means described next is provided to the computer portion 201.

[0058]

Fig.13 shows the flowchart of the nozzle profile data 211 adjusting means. First, an overlapped portion and a peak value are detected in the following manner.

Registers for a dot cycle are prepared. In this embodiment, because the pulse data 1 and the y coordinate of the nozzle are defined at 4800 dpi, 16 registers r15, r14, ..., r0 are prepared.

A pulse data 1 (a7, a6, a5, a4, a3, a2, a1, a0, b7, b6, b5, b4, b3, b2, b1, b0) and a y coordinate value for each nozzle are retrieved from the nozzle profile data 211.

The pulse data 1 is rotated by the y coordinate value. For example, the pulse data 1 may result in (a2, a1, a0, b7, b6, b5, b4, b3, b2, b1, b0, a7, a6, a5, a4, a3). Then, they are added to the registers.

The same process is repeatedly executed for all the nozzles, then a maximum value of the registers is determined and set as a peak value. The peak value is compared with a predetermined maximum value. If the peak value is equal to or smaller than the predetermined maximum value, then the process is ended, and the updated nozzle profile data is output. If the peak value is greater than the predetermined maximum value, the peak value is leveled in the following manner. The y coordinate of the nozzle profile data 211 of a nozzle whose pulse indicated by the rotated pulse data 1 has a center near the peak value is updated. Specifically,

the y coordinate is updated such that the center of pulse indicated by the rotated pulse data 1 moves away from the peak value. As a result, the number of nozzles that have a pulse overlapping with the peak value is decreased, so the peak value is leveled. Then, the process is returned to calculate the overlapped portion and detect the peak value.

[0059]

In this way, the peak value at the overlapping portion will be lowered below the predetermined maximum value. As a result, the same effect as those obtained by the above-described multishift operation can be obtained. At this time, correction accuracy (the second stage) of the impingement position is somewhat lowered. However, the effects of the nozzle profile data 211 adjusting means on the impingement position is only 1/16 dot or 2/16 dot, which is too small to cause any problems in image quality.

[0060]

Next, other embodiment will be described while referring to Figs. 14, 15, 16, 12 and 11.

[0061]

In the above-described embodiments, it is assumed that the print head 207 ejects an ink droplet along a normal line, that is, in a direction perpendicular to the ejection surface. However, an actual ink droplet is ejected in a direction slightly angled with respect to the normal line.

Furthermore, the angle differs among the nozzles and is not generated only in the y direction. This embodiment corrects error on impingement position caused by such a direction difference of each nozzle.

[0062]

Fig. 14 shows a configuration of the recording head 207 in this embodiment. Nozzles 1402 aligned on a recording head ejection surface 1401 is the same as what was explained in Fig. 7. However, in this embodiment, deflection electrodes 1403 are provided between the nozzles 1402 and a recording sheet. The deflection electrodes 1403 only for the third nozzle line are shown in Fig. 14, but the deflection electrodes 1403 are provided for all of the first nozzle line through the tenth nozzle line.

[0063]

Fig. 15 shows a cross-sectional view in parallel with the recording head ejection surface as view from a nozzle line direction. The deflection electrodes 1430-1, 1430-2 are provided to the recording sheet 1501 side from the nozzle 1402 of the recording head ejection surface 1401. The deflection electrode 1430-1 is applied with a deflection voltage Vc (>0: constant) and a bias voltage Vb (>0: constant). The deflection electrode 1403-2 is applied with a deflection voltage -Vc (which has an opposite polarity of the deflection electrode 1403-1) and also with a bias

voltage Vb (which has the same polarity with the deflection electrode 1403-1). A deflection electric field element Ec having a rightward direction in Fig. 15 corresponding to a deflection voltage difference 2Vc is generated between the deflection electrodes 1403-1 and 1403-2. Also, because the recording head ejection surface 1401 is formed from a conductive material and is grounded, a deflection electric field element Eb having a downward direction in Fig. 15 corresponding to the deflection difference Vb is generated near the nozzle 1402.

[0064]

When an ink droplet 1502 is ejected, the ink droplet 1501 is charged to the positive charge (a charging amount q) by the electric field element Eb. The positively charged ink droplet 1502 is deflected rightward in Fig. 15 by the deflection electric field element Ec. Accordingly, the impingement position of the ink droplet 1502 is shifted to the righ. In Fig. 14, an angle $\theta$ of the nozzle lines with respect to the x direction is set to 83 degrees in this embodiment. Therefore, the x direction and the direction of the deflection electric field Ec can be regarded as the same direction. For this reason, the direction of the deflection electric field Ec is regarded as the x direction in the following description.

[0065]

There have been proposed a various different techniques to charge and deflect the ink droplet 1502 by the deflection electric field between the nozzle 1402 and the recording sheet 1501, so various deflections are realizable. However, it is assumed that a uniform deflection electric field Ec is generated between the nozzle 1402 and the recording sheet 1501 in this embodiment in order to simplify the explanation. Accordingly, the deflection amount of the ink droplet 1502 will be calculated without taking the influence caused by the electric field element Eb into consideration.

[0066]

If the ink droplet 1502 is ejected from the nozzle 1402 located at a position having a x coordinate value of zero in a direction perpendicular to the recording head ejection surface 1401, an impingement position x on the recording sheet 1501 is calculated by the following equation.

[0067]

[E2]

$$x = x0 + \frac{Ec}{2} \cdot \frac{q}{m} \cdot \left(\frac{D}{Vd}\right)^2$$

[0068]

When the ink amount m is fixed, then the charging amount q is substantially constant. Therefore, when the ejection speed Vd is changed while the ejection amount m is

unchanged, then the impingement position x can be corrected. This is a specific effect of this embodiment and can correct the impingement position x which was impossible to change in the above-mentioned embodiment.

[0069]

Fig. 16 shows a control method of this embodiment. In this invention, the profile data update means 1601 in the computer portion 201 can update the y coordinate value and the pulse data 1 of the nozzle profile data 211 based on specified impingement positions x and y and ejection amount m. All the impingement positions x and y and the ejection amount m of each nozzle can be adjusted at the same time by inputting the updated nozzle profile data 211 to the above-described printer engine portion 202. The profile data update means 1601 is explained next.

[0070]

In this embodiment, the profile data update means 101 of Fig. 1 executes an updating process including three stages described below.

[0071]

(First Stage)

In a first stage of the nozzle profile data 211 updating process, the ejection amount m of each nozzle is adjusted to a target value. The profile data update means 1601 in Fig. 1 has a table indicating the characteristic

between the voltage non-application time Tsplit(μs) and the ejection amount m(ng) in Fig. 12. The profile data update means 101 determines the pulse data 1 based on the table of the characteristic between the voltage non-application time Tsplit(μs) and the ejection amount m(ng) and the specified ejection amount m and updates the nozzle profile data 211.

[0072]

Fig. 12 shows characteristics between a voltage non-application time Tsplit (μs) and an ejection speed Vd(m/s) and between the Tsplit (μs) and an ejection amount m(ng), for when a driving pulse with a time width Tw is divided by the voltage non-application time with a time width Tsplit (μs) at its center. The time width Tw is set to Tn/2 (=9μs) shown in Fig. 11. The same effect will be obtained by replacing the characteristic between the time width of the driving pulse and the ejection amount with the characteristic between the voltage non-application time Tsplit (μs) and the ejection amount m (ng). The method to change the pulse data 1 is the same as that explained in Fig. 18, so the explanation will be omitted here. The ejection amount m can be adjusted by this method.

(Second Stage)

Next, in a second stage of the nozzle profile data 211 updating process, the impingement position x of each nozzle is adjusted to a target position. A test printing is

performed, and the measuring unit 1602 measures an actual impingement position x and inputs the measured impingement position x to the profile data update means 101. Although the measuring unit 1602 is the same as the measuring unit 102 in Fig. 1, the measuring unit 1602 can measure x and y coordinate of the center of dot. The profile data update means 101 calculates the ejection speed Vd from (E2) based on a difference between the measured impingement position x and the target impingement position x. The correction of the ejection speed Vd is achieved by adjusting the time width of a driving pulse based on the characteristic between the time width of the driving pulse and the ejection speed shown in Fig. 11. As described above, the ejection amount m changes only slightly in response to the change in the ejection speed Vd as indicated by the characteristic between the time width of the driving pulse and the ejection speed Vd. Therefore, slight change in the time width of the driving pulse hardly changes the ejection amount m. In this way, the ejection speed Vd is corrected without changing the ejection amount m.

[0073]

(Third Stage)

Finally, in a third stage of the nozzle profile data 211 updating process, the impingement position y of each nozzle is adjusted to a target position. A test printing is

performed again, and the measuring unit 1602 measures an actual impingement position y and inputs the measured impingement position y to the profile data update means 101. The profile data update means 101 adds to the y coordinate value of the nozzle profile data 211 based on a difference between the measured impingement position y and the target impingement position y. As the (E1) shows, y0 is adjusted by this process, so the impingement position y is changed properly.

[0074]

In the above-described three-stage process, the impingement positions x and y and the ink ejection amount m of each nozzle can be set to values within predetermined regions. Therefore, in a line-scan type ink jet recording device including a drop-on-demand ink jet print head, a high speed ink jet recording device capable of reliably printing a high quality image can be provided.

[0075]

Next, other embodiment of the present invention will be explained while referring to Figs. 21 and 20.

[0076]

According to the above-described embodiments, the time resolution for determining the driving pulse voltage waveform is 1/16 of the time duration Td (μs) that is required for recording a single dot. Therefore, in a

printer system where a printing (sheet feed) speed Vp must be changed, the Td is changed, thereby changing the driving pulse voltage waveform. The driving pulse voltage waveform is determined in accordance with the nozzle characteristics described above, and is not directly related to the printing speed Vp. It is undesirable for the driving pulse voltage waveform to change in association with the printing speed Vp. Also, when the time width of driving pulse is small relative to the time duration Td (μs), there was a problem that the time resolution for determining the driving pulse voltage waveform is undesirably rough. In order to overcome the above-problems, according to this embodiment, the time resolution of the pulse data, which determines the preciousness of impingement position y, is set to a predetermined value, while the time resolution for the y coordinate value is set to 1/16 of a single dot in the same manner as described in the above embodiments.

[0077]

Fig. 21 shows a circuit composition of a data speed converting unit of this embodiment. This circuit is provided near the piezoelectric element driver 206 in Fig. 2. The driving data 212 is led to a rising point detecting circuit 2102. Upon detecting a rising point of the driving data 212, a self-stop type counter 2103 is started. The self-stop type counter 2103 counts a driving data clock 2104

which is synchronized with the driving data 212. Having counted eight clocks, the self-stop type counter 2103 stops driving. On the other hand, the driving data 212 is also led to a logical multiplication 2105. When a signal 2106 from the counter 2103 is "1", the driving data 212 is input to the shift register 2101 which is formed from eight D-flip-flops in this embodiment. The driving data clock 2104 is input to a clock of the shift register 2101 through a selector 2107, so eight bits of the driving data 212 is stored. Subsequently, a self-stop type counter 2108 starts at an end of the signal 2106. The self-stop type counter 2108 counts a pulse data clock 2109 from a predetermined external device, and stops counting after having counted eight clocks. When a signal 2110 from the counter 2108 is "1", the selector 2107 selects the pulse data clock 2109 (which generally has a frequency higher than that of the driving data clock 2104), and the shift register 2101 outputs the eight bits of the driving data 212, which have been stored earlier, to the piezoelectric element driver 206. Such a circuit is provided near each of all the piezoelectric drivers 206.

[0078]

Operations of the data speed converting unit will be described while referring to Fig. 20. The driving data 212 includes a single start bit 2001 followed by eight-bit pulse

data, which is 3c(0011 1100) in the hexadecimal number system in Fig. 20. The eight-bit pulse data is followed by seven bits of "0", then the start bit follows. The same pattern is repeated at 16 bits cycle. The piezoelectric element driver 206 starts outputting a high voltage driving signal 2002 directly after the pulse data in synchronization with the pulse data clock 2109 from the external device is output.

[0079]

According to this embodiment, even when the driving data clock 2104 changes as a result of the change in the print (sheet feed) speed Vd, the driving pulse voltage waveform is maintained at a constant form. Therefore, the ink ejection characteristics will be maintained unchanged. Also, the time resolution for determining the driving pulse voltage waveform is not related to the time duration Td(μs), and usually, the time resolution is set small, so that even when the time width of driving pulse is small compared with the time duration Td, highly precise modulation can be performed.

[0080]

[Effect of The Invention]

According to the present invention, in a line scan ink jet recording device including a drop-on-demand ink jet print head, it is possible to control both an ejection

amount and an impingement position of an ink droplet on a recording medium for each of a plurality of nozzles. Accordingly, a high quality image can be formed. Also, a nozzle profile data is updated based on either target ink ejection amount and a target impingement position or their measurement values. Therefore, unevenness and fluctuation in ejection characteristics among the nozzles can be dealt with. Further, because a generation timing of all driving pulse is controlled, change in a size and a shape of an ink droplet and an impingement position due to interference can be also prevented.

[Brief Description of The Drawings]

[Fig. 1] A block diagram showing a configuration of a control method in a nozzle data converting portion 204.

[Fig. 2] A block diagram showing an overall configuration of a printer system according to the present invention.

[Fig. 3] A schematic cross-sectional view showing a structure of a nozzle used in this invention.

[Fig. 4] A schematic view showing a printing result recorded by the printer system.

[Fig. 5] A schematic side view of a recording head 207 and a sheet 408.

[Fig. 6] A view of file structure of a nozzle profile data 211.

[Fig. 7] A plan view showing the recording head 207 as

viewed from an ejection surface side.

[Fig. 8] A view showing a definition of pulse data.

[Fig. 9] A view showing a method of converting bitmap data 210 into pulse replacing data.

[Fig. 10] A graph showing characteristics between a driving pulse voltage and an ejection speed and between the driving pulse voltage and an ejection amount.

[Fig. 11] A graph showing characteristics between a time width of a driving pulse and an ejection speed and between the time width of the driving pulse and an ejection amount.

[Fig. 12] A graph showing characteristics between a voltage non-application time and an ejection speed and between the voltage non-application time and an ejection amount.

[Fig. 13] A flowchart of a profile data 211 updating means.

[Fig. 14] A plan view showing a configuration of the recording head 207 according to the present invention

[Fig. 15] A cross-sectional view of Fig. 14 as viewed from a nozzle line direction.

[Fig. 16] A block diagram showing a control method of the recording head of Fig. 14.

[Fig. 17] A diagram showing a method of changing a certain pulse data 1 in the profile data update means 101.

[Fig. 18] A diagram showing a method of changing a certain pulse data 1 in the profile data update means 101.

[Fig. 19] A smoothing circuit of a piezoelectric element

used for driving multiple pulses.

[Fig. 20] A diagram showing an operation of a data speed converter.

[Fig. 21] A block diagram showing circuit configuration of the data speed converter of an embodiment.

[Description of Code]

101···profile data update means, 102···measuring unit, 201···computer portion, 202···ink jet printer engine portion, 203···RIP portion, 204···nozzle data converting portion, 205···controller, 206··· piezoelectric element driver, 207···recording head, 208···sheet feed unit, 209···document data, 210···bitmap data, 211···nozzle profile data, 212···driving data, 301···orifice, 302···pressure chamber, 303···diaphragm, 304···piezoelectric element, 305···signal input terminal, 306···piezoelectric element supporting substrate, 307···restrictor, 309···resilient member, 310···restrictor plate, 311···pressure chamber plate, 312···orifice plate, 313···supporting plate, 401-405···dots recorded at every other pixel, 406···recording sheet, 1401···recording head ejection surface, 1402···nozzle, 1403···deflection electrode, 1501···recording sheet, 1502···ink droplet, 1601···nozzle profile data update means, 1901···equivalent circuit of the piezoelectric element 304, 2001···start bit, 2101··· shift register, 2102··· rising point detecting circuit, 2103··· self-stop type counter, 2104···driving data clock, 2105···logical multiplication, 2106···

signal from the counter 2103, 2107…selector, 2108…self-stop type counter, 2109…pulse data clock, 2110…signal from the counter 2108

[Document Name] Abstract

[Abstract]

[Object] In a drop-on-demand ink jet type recording head, it is difficult to produce a large number of nozzles to the same ink ejection characteristic, and an unevenness in recording quality such as an uneven line and an uneven density will result. Also, the ejection characteristic has become uneven for some reasons during operation of a recording device.

[Configuration] In order to adjust an impingement position on a sheet and an ejection amount of an ink droplet for each nozzle, a recording signal for each nozzle is converted into a driving data finer than a conventional pixel by using a nozzle profile data which describes a pulse voltage waveform apply to a piezoelectric element and a generation timing thereof.

[Selected Drawing] Fig. 1